SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES IN THE DES MOINES RIVER, IOWA

An abstract of a Thesis by
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Problem. Evaluation of the water quality of the Des Moines River, Iowa by sampling and analyzing the benthic macroinvertebrate community.

Procedure. Artificial substrates at four stations were used to collect benthic macroinvertebrates. Community structure was analyzed with species diversity indices. Species diversity ($\bar{D}$) and redundancy (R) values were used to calculate standardized distance (SD) values. The indices were analyzed statistically.

Findings. The average $\bar{D}$ values ranged from 1.62 to 1.94. Mean standardized distance (SD) values were lowest immediately above the metropolitan Des Moines area and highest immediately downstream from the metropolitan Des Moines area.

Conclusion. According to species diversity ($\bar{D}$) values, the entire Des Moines River in the study area exhibited mild pollution. Differences in community structure do exist in the river. Differences in standardized distance (SD) values are attributed to influences that the metropolitan area had on the river. Red Rock Reservoir showed no statistically significant effects on the station immediately downstream.

Recommendations. Recommendations for further study are: (1) Follow-up species diversity and productivity studies after Saylorville Reservoir is impounded. (2) Follow-up study with more sample sites between stations 2 and 3 incorporating chemical analysis of water to pinpoint the site of most drastic water quality change.

SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES IN THE DES MOINES RIVER, IOWA

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INTRODUCTION

The Des Moines River is the largest river flowing through Iowa. It originates in a glacial moraine in southwestern Minnesota and flows through the middle of Iowa, angling to join the Mississippi River at the southeastern corner of Iowa. The Des Moines River is 535 miles in length and has a total drainage area of 15,800 square miles of which approximately 95% is devoted to agriculture. For approximately 120 miles of its course through Iowa, the river is interrupted by the proposed Saylorville Reservoir, the metropolitan Des Moines area, the confluence of the Raccoon River (its major tributary), and Red Rock Reservoir.

The Des Moines River flows generally through agriculturally enriched soil areas. Water runoff from these fertilized fields enters the river carrying soil particles from the land into the river. Dissolved in the water are soluble nutrients while the soil particles carry adsorbed chemicals. The biological effects of these agricultural products is varied; nevertheless, the aquatic environment is potentially altered by them. The enriched water allows for the existence and growth of some organisms and inhibits the existence and growth of others. Algae blooms and areas of low dissolved oxygen may occur due to this enrichment.

Another factor which certainly affects the river is the presence of impoundments. Ingols (1959) showed that

impoundments on rivers affect the water chemistry, especially causing a decrease in the dissolved oxygen content of the water. This same effect, according to Kittrell (1959), caused a decreased pollution assimilation capacity of a stream. Water depth, temperature fluctuation, nutrient addition, siltation, turbidity, light penetration, and other factors caused by reservoirs may result in major alterations of the water environment with respect to physical, chemical, and biological parameters (Pfitzer, 1954; Churchill and Asce, 1958; Love, 1961; Isom, 1970; Spence and Hynes, 1971; Lehmkuhl, 1972).

A third factor that can change stream morphology and physico-chemical properties of a river is the influence of a metropolitan area. Runoff water from industrial sources, effluent from waste disposal sites, and warmed water from use in industrial cooling may influence the makeup of the receiving water.

The study of the influences that these and other factors have on a river is complex. Without considerable time, many people, and expensive equipment the study cannot be completed by direct or constant measurement of all parameters. Some other method of determining the effects of man-influenced factors on the river must be utilized. One useful method is the examination of aquatic biological communities as they respond to these factors.

Since benthic macroinvertebrates are biologically

important to a stream, and since benthic macroinvertebrates remain fixed to a particular spot in the river and do not normally move great distances, and since they are reasonably sensitive to their environment, they can be studied to indicate the effects of the above mentioned factors. Benthic macroinvertebrates are indicative of both present and past environments (Wilhm, 1967). Some of the variation in population size or structure of the benthic macroinvertebrate community could presumably indicate a fluctuation in such factors as temperature, turbidity, rheotactic deprivation, water level fluctuation, and light penetration. Also, benthic macroinvertebrates can be quantitatively sampled and statistically analyzed (Mathis and Dorris, 1968). These factors make benthic macroinvertebrates a convenient and useful measure of stream conditions.

Benthic organisms have been used extensively for evaluating stream conditions (Gaufin and Tarzwell, 1952, 1956; Beck, 1954; Hynes, 1958, 1963; Scott, 1958; Beak, 1964; Wilhm and Dorris, 1966, 1968; Wilhm, 1967, 1970; Harrel and Dorris, 1968; Mathis, 1968; Mathis and Dorris, 1968; Arthur and Horning, 1969; Gallup, Robertson, and Streebin, 1970; Jacobi, 1971; Spence and Hynes, 1971; Lehmkuhl, 1972). Benthic macroinvertebrates have been collected by several methods and analyzed in various ways by these investigators.

Of the several possible ways to study the response of benthic macroinvertebrates to their environment, one is the

measure of the biomass or the production of the organisms in the community. This method deals with the flow of matter and energy. Another method deals with the structure of the community. Margalef (1961) stated that biotic diversity measured the matter and energy capacity of the community or the maximum information that could be transmitted by the community.

The simplest, most common, and most promising method of measuring the structure of a community is the utilization of species diversity indices (Wilhm and Dorris, 1966). Gallup, Robertson, and Streebin (1970) stated that the most efficient parameter for assessing pollution in a stream receiving organic wastes was the measurement of species diversity in a benthic macroinvertebrate stream community.

Harkins and Austin (1971) outlined a method for evaluating biological data using a species diversity index. This index is a dimensionless number whose size expresses an estimate of the relative magnitude of some condition such as the response of aquatic insects to a pollutant and is of such a nature that statistical inferences can be made from it. This index combines diversity per individual and redundancy where redundancy is an expression of dominance of one or more species. It is inversely proportional to the wealth of the species, i.e., when redundancy is zero, each individual belongs to a different species; when redundancy is 1.0 it indicates that all individuals belong to the same

species (Wilhm, 1967).

When the diversity per individual increases and the redundancy decreases, this indicates an "improved" stream condition and a more random distribution of species. When the diversity per individual decreases and redundancy increases, it indicates varied or "worsened" stream order (Harrel and Dorris, 1968). A "healthy" stream is one in which conditions are maintained which are capable of supporting a great variety of organisms (Patrick, 1949).

These indices have been used rather extensively (Lloyd and Ghelardi, 1964; Pielou, 1966; Wilhm and Dorris, 1966, 1968; Wilhm, 1967, 1970; Harrel and Dorris, 1968; Mathis and Dorris, 1968; Gallup, Robertson, and Streebin, 1970; Hurlbert, 1971; Dickson and Cairns, 1972) either to measure the structure of aquatic communities or to assess the effects of an environmental impact.

The objective of this study was to assess the biological community structure of the Des Moines River in four locations as influenced by a reservoir and a large metropolitan area, using artificial substrate as the collecting device and using species diversity indices for statistical comparisons of the community structure at these sites on the river.

METHODS AND MATERIALS

Benthic macroinvertebrates were collected at each of four sites in the Des Moines River (Table 1). Site number one was upstream from the proposed Saylorville Reservoir. Site number two was downstream from the proposed reservoir but upstream from the metropolitan Des Moines area. Site number three was downstream from the metropolitan Des Moines area but upstream from the Red Rock Reservoir. Site number four was downstream from Red Rock Reservoir. The distance between the extreme sites is approximately 120 river miles (Figure 1).

Artificial substrate samplers were used to collect the benthic macroinvertebrates. Artificial substrate samplers have been shown to be the most effective method for the collection of the greatest number of species of benthic macroinvertebrates in a stream (Arthur and Horning, 1969). Artificial substrates can be used when the texture of the stream bed is not conducive for the colonization of a variety of bottom organisms. These substrata provide living space for a multiplicity of drifting and naturally propogated organisms (MacKenthun, 1966). Artificial substrate offers a uniform and more precise surface area than conventional methods (Kennedy, 1971). Others using artificial substrates for the collection of benthic macroinvertebrates have been Scott (1958), Grzenda and Brehmer (1960), Kevern, Wilhm, and

Table 1. Location and description of sampling stations.

STATION	KILOMETERS*	DESCRIPTION
1	407.3 (253.0 miles)	U. S. Highway 30 bridge, 1.6 kilometers west of Boone; 49.2 kilometers upstream from Saylorville Dam
2	340.4 (211.4 miles)	N. W. 66th St. Bridge, 3.2 kilometers east of Camp Dodge; 3.0 kilometers downstream from Saylorville Dam
3	312.5 (194.1 miles)	Vandalia bridge (IPALCO bridge), State Route 46, 81.5 kilometers upstream from Red Rock Dam
4	210.7 (130.9 miles)	Tracy bridge, State Route 92; 16.0 kilometers downstream from Red Rock Dam

*Kilometers above junction with Mississippi River

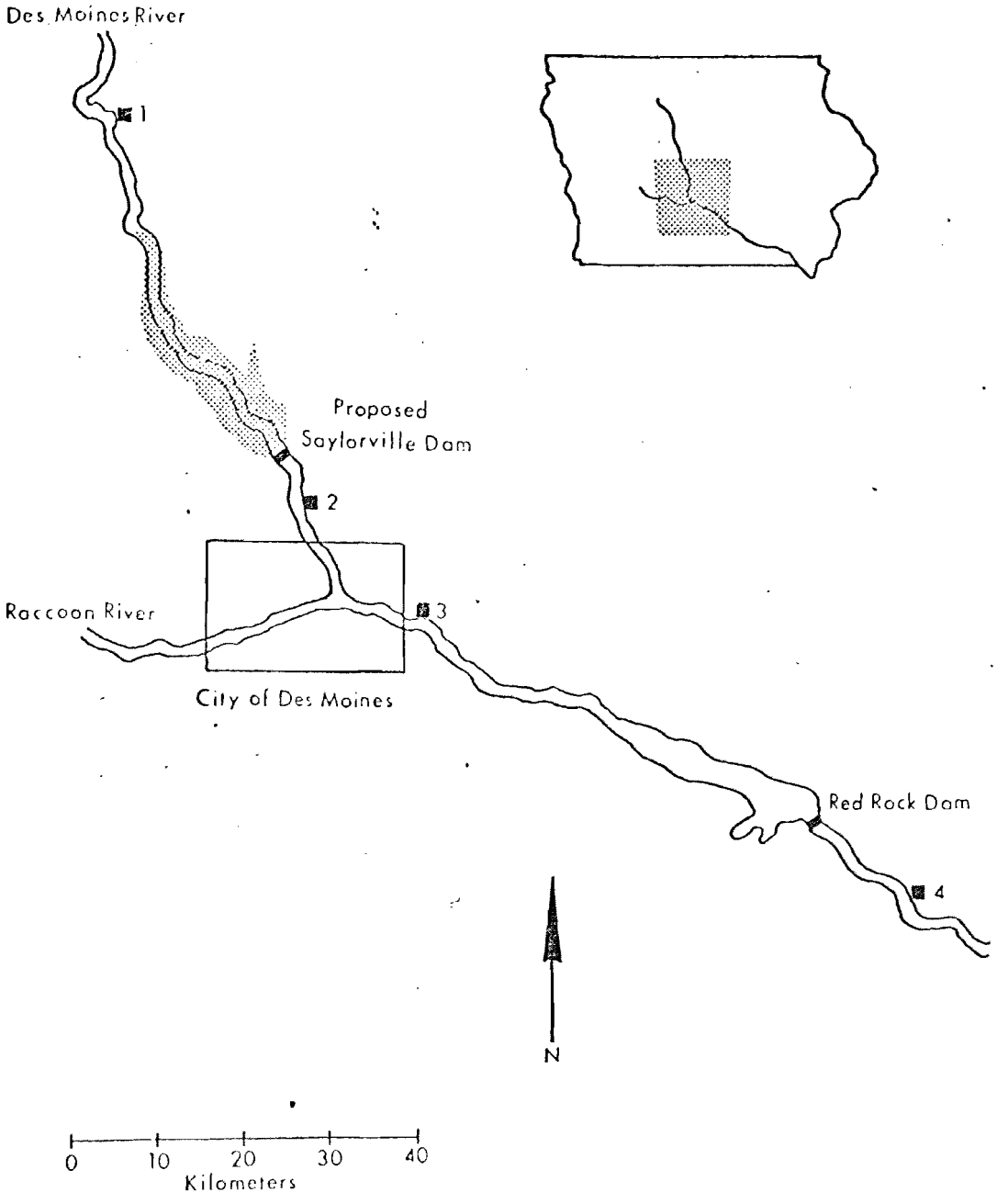

Figure 1. Map of study area showing Red Rock Dam, proposed Saylorville Dam and four sampling stations.

Van Dyne (1966), MacKenthun (1966), Mason, Anderson, and Morrison (1967), Arthur and Horning (1970), and Jacobi (1971).

The artificial substrate sampler used to collect the benthic macroinvertebrates consisted of six barbeque baskets each filled with ten concrete spheres. The baskets were attached to a flotation unit which consisted of three 5-gallon cans bolted to a 2-inch by 70-inch galvanized steel pipe. The cans were filled with polyurethane foam to increase buoyancy. The upstream side of each can was connected through a rod coupler and a ring and eye bolt to 1/4-inch cable. This cable surrounded a bridge support located in the main flow of the river, and was long enough to allow the float to be tethered 4 to 5 meters downstream from the bridge support.

Six 3/8-inch by 5-inch eye bolts were attached to the pipe for suspension of the six barbeque baskets containing the concrete spheres. The spheres for the artificial substrate were made of ready-mix concrete. Plaster molds were made to form the concrete into uniform surfaces each with an approximate diameter of 7.5 cm and with an exposed surface area of 178 cm^2 per sphere and 0.18 m^2 per basket.

The sampler was suspended in the water and each month (beginning in April 1970 and continuing until September 1971) the cement spheres were removed from the float mechanism and the benthic macroinvertebrates were removed. The spheres were

replaced in the basket and the basket was replaced in the river. The organisms were concentrated in a U. S. Standard Number 30 sieve and preserved in 70% alcohol. In the laboratory the organisms were separated from extraneous debris by sugar flotation (Anderson, 1959). The organisms were sorted into "operational" species and counted using a dissecting microscope. This method of sorting according to obvious morphological differences has been shown to be effective in other similar studies (Cairns and Dickson, 1971).

This information was analyzed using the method of Harkins and Austin (1971); this method for evaluating biological data was a modification of Wilhm's (1967) method for determining diversity (D), diversity per individual ($\bar{D}$), redundancy (R), and standardized distance (SD).

Wilhm (1967) proposed that:

$$D = \sum_{i=1}^{S} n_i \log_2 \frac{n_i}{N}$$

where D is the diversity and S represents the number of species, N represents the total number of organisms, and n_i represents the number of organisms in the i^{th} species. Also,

$$\bar{D} = \frac{D}{N}$$

where $\bar{D}$ represents the average information contributed by individuals to the community, or the diversity per individual.

Another diversity index used was redundancy (R), the

measure of dominance of one or more species in the community, where:

$$R = \frac{D_{max} - D}{D_{max} - D_{min}}$$

The two indices, R and $\bar{D}$ were ranked from low to high for incorporation in the calculation of a new index, standardized distance (SD).

The standardized distance from a control point or "biological desert" condition was computed from the equation:

$$SD_i = \frac{(\text{Rank } R_i - \text{Rank } R_c)^2}{\text{Var } (R)} + \frac{(\text{Rank } \bar{D}_i - \text{Rank } \bar{D}_c)^2}{\text{Var } (\bar{D})}$$

where $\bar{D}$ and R were reduced to a single index value per sample utilizing a nonparametric discrimination technique (Harkins and Austin, 1971). The magnitude of this value is a measure of the relative "well being" of the sampling station; i.e., the larger the SD value, the farther the station is from a "biological desert" condition.

Values of SD were compared using a two-way analysis of variance to see if there was any significant statistical difference with respect to time or station site.

RESULTS

Organisms collected represented seven orders of aquatic insects (Trichoptera, Diptera, Ephemeroptera, Coleoptera, Plecoptera, Megaloptera, Odonata), one order of arachnid (Acarina), and one order of Coelenterata (Hydrariae). The total number of organisms collected over the sampling period is shown in Table 2. Trichoptera was the most abundant order, followed by Diptera and Ephemeroptera. The orders of Coleoptera, Plecoptera, Megaloptera, Odonata, Acarina, and Hydrariae were less abundant. Megalopterans were never observed at stations 2 and 4. Acarina were never collected at stations 1 and 3. Coelenterates were only observed at station 4.

Biological data and species diversity data for the various stations are listed in Tables 3-6. The missing data as seen in these tables was caused by the loss of the sampling baskets or by loss of the entire float mechanism due to ice floes, high water, and snags. The number of species ranged from one species in December 1970 at station 4 to 15 species in August 1970 at station 1. Generally, the number of species was reduced throughout the winter. The number of organisms ranged from 12 in March 1971 at station 4 to 3,264 in September 1970 at station 2. The highest number of organisms usually occurred in late summer and fall; the lowest number was generally in winter.

Table 2. Total number of benthic macroinvertebrates collected on artificial substrate sampler from the Des Moines River, April 1970 through September 1971.

	Stations			
Taxa	1(13)*	2(11)	3(11)	4(13)
Trichoptera	6375	4454	1990	5968
Diptera	2954	5608	1116	263
Ephemeroptera	1745	1079	561	871
Coleoptera	46	6	3	4
Plecoptera	29	8	67	15
Megaloptera	10	0	3	0
Odonata	7	3	2	6
Acarina	0	58	0	24
Coelenterata (Hydra)	0	0	0	557

*Number in parenthesis indicates number of individual samples

Table 3. Summary of data for macroinvertebrates collected on artificial substrates at Station 1 from April 1970 through September 1971, including R (redundancy), $\bar{D}$ (diversity per individual), and SD (standardized distance).

Sample date	Number of species	Number of organisms	R	$\bar{D}$	SD
April 1970	13	563	0.62	1.48	0.77
May	13	871	0.65	1.38	0.44
June	--	--	----	----	-----
July	12	2039	0.45	1.98	5.57
August	15	1954	0.42	2.30	11.92
September	9	1444	0.76	0.81	0.01
October	11	1117	0.34	2.30	15.50
November	7	585	0.29	1.99	12.81
December	9	322	0.35	2.08	10.72
January 1971	4	282	0.41	1.19	2.66
February	6	114	0.44	1.49	2.35
March	--	--	----	----	(12.65)*
April	--	--	----	----	----
May	--	--	----	----	----
June	--	--	----	----	----
July	11	898	0.40	2.08	8.56
August	10	681	0.22	2.58	20.37
September	12	524	0.30	2.50	18.25

*Number in parenthesis indicates estimated values

Table 4. Summary of data for macroinvertebrates collected on artificial substrates at Station 2 from April 1970 through September 1971, including R (redundancy), $\bar{D}$ (diversity per individual), and SD (standardized distance).

Sample date	Number of species	Number of organisms	R	$\bar{D}$	SD
April 1970	11	386	0.49	1.81	2.87
May	9	287	0.64	1.24	0.28
June	--	--	----	----	----
July	7	181	0.43	1.64	3.23
August	8	1121	0.73	0.85	0.03
September	9	3264	0.66	1.10	0.12
October	10	2310	0.42	1.93	5.61
November	6	173	0.40	1.57	4.08
December	6	229	0.26	1.90	12.20
January 1971	8	143	0.46	1.70	2.57
February	--	--	----	----	(5.16)*
March	--	--	----	----	(8.84)
April	--	--	----	----	----
May	--	--	----	----	----
June	--	--	----	----	----
July	10	567	0.33	2.23	15.21
August	--	--	----	----	(7.46)
September	10	2505	0.44	1.88	4.89

*Number in parenthesis indicates estimated data

Table 5. Summary of data for macroinvertebrates collected on artificial substrates at Station 3 from April 1970 through September 1971, including R (redundancy), $\bar{D}$ (diversity per individual), and SD (standardized distance).

Sample date	Number of species	Number of organisms	R	$\bar{D}$	SD
April 1970	12	462	0.38	2.23	12.31
May	--	--	----	----	(4.21)*
June	--	--	----	----	----
July	10	425	0.18	2.68	22.03
August	10	345	0.40	2.03	8.47
September	5	143	0.34	1.53	6.46
October	8	257	0.29	2.12	14.91
November	7	57	0.15	2.24	19.58
December	4	14	0.43	1.28	2.24
January 1971	5	32	0.18	1.76	12.18
February	--	--	----	----	(12.37)
March	--	--	----	----	(16.05)
April	--	--	----	----	----
May	--	--	----	----	----
June	--	--	----	----	----
July	11	1842	0.30	2.42	18.22
August	4	57	0.21	1.52	10.30
September	6	111	0.41	1.57	3.68

*Number in parenthesis indicates estimated data

Table 6. Summary of data for macroinvertebrates collected on artificial substrates at Station 4 from April 1970 through September 1971, including R (redundancy), $\overline{D}$ (diversity per individual), and SD (standardized distance).

Sample date	Number of species	Number of organisms	R	$\overline{D}$	SD
April 1970	6	621	0.37	1.64	6.19
May	8	608	0.60	1.23	0.37
June	--	--	----	----	----
July	--	--	----	----	(9.40)*
August	6	75	0.34	1.71	7.06
September	7	780	0.21	2.22	17.63
October	8	711	0.57	1.33	0.65
November	6	60	0.15	2.08	16.08
December	1	324	1.00	0.00	0.00
January 1971	5	13	0.22	1.62	10.34
February	6	22	0.14	1.96	14.70
March	4	12	0.10	1.47	12.20
April	--	--	----	----	----
May	--	--	----	----	----
June	--	--	----	----	----
July	10	1289	0.46	1.82	3.68
August	7	2189	0.46	1.52	1.79
September	8	1504	0.47	1.61	2.08

*Number in parenthesis indicates estimated data

The redundancy values ranged from 0.10 to 1.00, nearly the complete range of possible variation. Both extremes in redundancy occurred at station 4. The $\bar{D}$ values ranged from 0.00 to 2.68 with no noticeable trend as to station site or time. The SD value ranged from 0.00 to 22.03; generally, the higher values were observed in fall and winter.

Table 7 shows the mean values of the biotic and species diversity data. The mean number of species ranged from 6 to 10; while the mean number of organisms ranged from 340 at station 3 to 1,015 at station 2. The mean $\bar{D}$ values for all stations was between 1.0 and 2.0. The average SD values ranged from 4.64 at station 2 to 11.85 at station 3.

An analysis of variance (Table 8) revealed no significant difference among SD values with respect to time; however a significant difference did exist among stations. This analysis was facilitated by estimating eight pieces of data (Tables 3-6); this is reflected in the loss of degrees of freedom required for significance; df=3/31 rather than 3/39.

Since differences existed among the four stations, at least two of the stations were different, but there could be as many as four different station means. The F test (Table 8) does not provide information as to the specific number of differences. To identify where the differences were, all possible combinations of station means were compared using

Table 7. Mean number of species, mean number of organisms, mean R (redundancy), mean $\bar{D}$ (diversity per individual), and mean SD (standardized distance) values, with corresponding standard error (S.E.) values for each sampling station.

	Station			
Mean value	1	2	3	4
Number of species (±S.E.)	10(±3)	8(±3)	7(±2)	6(±2)
Number of organisms (±S.E.)	876(±185)	1015(±118)	340(±115)	631(±46)
R(±S.E.)	0.43(±0.12)	0.40(±0.14)	0.25(±0.09)	0.39(±0.09)
$\bar{D}$(±S.E.)	1.86(±0.52)	1.62(±0.50)	1.94(±0.60)	1.55(±0.42)
SD(±S.E.)	8.45(±1.46)	4.64(±0.17)	11.85(±3.20)	7.13(±1.05)

Table 8. Analysis of variance summary for standardized distance (SD) values.

Source of variation	df	SS	MS	F
Total	55	2170.26	177.00	---
Time	13	509.98	39.23	1.13
Station	3	309.40	103.13	2.98*
Time-station interaction	39	1350.87	34.64	---

*Significant at the 0.05 level

Scheffe's (1953) test.

DISCUSSION

The average diversity per individual ($\bar{D}$) value for all stations ranged from 1.0 to 3.0 as seen in Table 7. Wilhm (1970) stated that $\bar{D}$ values usually vary between 3.0 and 4.0 in a clean water stream and are usually less than 1.0 in polluted streams. Since the mean values for the Des Moines River never fell below 1.0 or exceeded 3.0 the sites exhibited mild pollution according to Wilhm's evaluation of species diversity.

The SD mean values were used in the test of Scheffe (1953) and showed no difference among the station means. Because of the general ability to test any and all types of contrasts, Scheffe's method has a comparatively low sensitivity. Finding no significance using Scheffe's method does not negate the F test; therefore, the conclusion is that the extremes of the four station means are significant and that stations 2 and 3 are significantly different.

Station 3 was the farthest from the "biological desert" condition as indicated by a high relative SD value. Station 2, on the other hand, was nearest to the "biological desert" condition of the sites studied. Change of the environment must have occurred between station 2 and 3, making available additional niches for organisms, thus

increasing biotic diversity potential. Scott (1958) stated that mild organic pollution need not result in an imbalance of the biota of a stream as long as the added quantities are assimilable. Some of the possible sources of organic and inorganic additions to the river between station 2 and 3 are runoff waters from the metropolitan Des Moines area, added nutrients from the confluence of the Raccoon River with the Des Moines River, and nutrient input from the Des Moines sewage treatment plant.

Apparently the flux of organisms due to environmental conditions is a subtle one between stations 1 and 2 and between stations 3 and 4. The influence of Red Rock Reservoir on the community structure of station 4 was of little significance for the period of time of the study.

Kennedy (1971) showed that station 3 had the lowest biomass and annual production value for the same four stations and over the same time period of this investigation. The biomass was lowest at station 3 yet the species diversity ($\bar{D}$) was highest at station 3. Apparently, production is lower at station 3 but the number of species increased or remained relatively unchanged while the number of organisms decreased relative to the other stations. The effect of the metropolitan area seems to be a mild enrichment benefiting the community structure but depressing the production. Odum (1971) stated that while productivity or total energy flow certainly effects species diversity, the two quantities are

not related in any simple linear manner. Very productive communities can have either very high or very low species diversity. Stability seems more directly correlated with diversity than does productivity. Hurlbert (1971) suggested that gradients exist over which increases in species diversity are accompanied by decreases in species richness, where species richness means the number of species present in a collection containing a specified number of individuals or possibly quantity of biomass. This study seems to indicate that species diversity and productivity are estimates of two distinct features of biological associations. However, the two parameters considered together make a more useful measure of the biotic quality of a river than simply one of them alone.

The artificial substrate samplers used in this study have certain disadvantages. The benthos of a stream seems to be extremely dependent upon availability of substrate (Scott, 1958). Since The Des Moines River has little suitable substrate for the colonization of benthos because of the shifting nature of the sandy bottom, the artificial substrate sampler provided a means for the colonization and growth of certain organisms. The nature of the substrate, however, appears to select for attaching filter feeders and to select against burrowing forms (Dickson and Cairns, 1972).

The organisms which colonized on the cement spheres of the sampler may not represent the true benthos of the

stream, but rather drift volunteers. Drift is a temporary event in the life history of many benthic organisms causing the downstream movement of organisms (Waters, 1972). Lehmkuhl (1972) stated that drift and benthos were separate communities. Most users of artificial substrate suggest that they be used only to compare sites over a period of time rather than be an absolute indicator of organisms present. Values obtained using artificial substrate samplers are comparable only with the same sampler type and the same river conditions.

The use of species diversity indices for the determination of community structure has some advantages and disadvantages. One advantage is that the observer can get a statistical grasp of the community structure; these numbers can be analyzed for significance and correlations. "Equitability" or "evenness" is a factor of concern when dealing with species diversity indices. Evenness or equitability is a measure of the observed value of species diversity obtained as compared with the maximum diversity possible. In many cases the percentages or error due to evenness is great. In other words, sometimes the sample of the community is not a representative sample in that organisms are not equally distributed and tend to clump in natural environments. Evenness is a measure of how typical a sample is of the community being measured. In the calculation of SD values, redundancy (R) takes evenness into account to a certain extent as

redundancy is a measure of unevenness (Hurlbert, 1971) or inequitability (Lloyd and Ghelardi, 1964).

Lloyd and Ghelardi (1964) stated that the use of equitability in dealing with an incomplete sample from a non-localized source adds little to the total knowledge of the community. Since these data are selective, due to the use of artificial substrate samplers, the values should be used as relative values and not as indicators of the total benthic community.

CONCLUSION AND SUMMARY

The biotic community structure of the Des Moines River was assessed in several locations as influenced by a reservoir and a large metropolitan area. Artificial substrate samplers were used as the collecting device and species diversity indices were used for statistical comparison of the communities at various sites in the river. Results showed a significant difference existed between the station above the metropolitan area (station 2) and the station below the metropolitan area (station 3). The community farthest from a "biological desert" condition was the one immediately below the metropolitan area (station 3).

The following conclusions were drawn from the study:

1. According to Wilhm's evaluation of species diversity, mild pollution existed in all areas sampled of the

Des Moines River within the study site.

2. Species diversity of benthic macroinvertebrates used as a measure of water quality indicated that the quality of water in the Des Moines River changed as it flowed through the study area.

3. Based upon the results of this study, the river downstream from the city of Des Moines metropolitan area showed greatest species diversity; thus, the most stable community.

4. The number of organisms were generally fewer downstream from the Des Moines metropolitan area than in the other sample sites.

5. Red Rock Reservoir had no significant effect on the aquatic community structure of the downstream station.

6. Recommendations for future study:

   a. Follow-up species diversity and productivity studies after Saylorville Reservoir is impounded;

   b. Assessment of the effects of various physical and chemical parameters (such as dissolved oxygen, chlorine, suspended solids, temperature, and current velocity) on benthic macroinvertebrate distribution in a stream;

   c. Utilization of other aquatic communities (such as plankton-drift algae community, periphyton community, rooted aquatic plant community,

bacterial-detritus community, protozoan-detritus community) for analysis of the community structure for the measurement of the water quality of the river;

d. Follow-up study with more sample sites between stations 2 and 3 incorporating chemical analysis of water to pinpoint the area of most drastic change.

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